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ABSTRACT

This document examines how subjects accomplish the task of matching movements to the characteristics of the performance environment. Literature pertaining to this topic is reviewed from the areas of time/motion study of industrial tasks, timing of coincidence-anticipation tasks, and cinematographic analysis of motor skill performance. A research sequence involving multidimensional analysis, combining both behavioral and cinematographic measures, is presented. The focus is on evluating both commonalities of movement organization across subjects and their relationship to environmental characteristics. Possible strategies are suggested for the teacher and learner concerned with skill acquisition. (Author/PB)

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AN INFORMATION-PROCESSING APPROACH TO SKILL ACQUISITION: MOVEMENT ORGANIZATION

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The performance of a motor skill involves the execution of a sequence of organized activity in relation to a particular situation. Acquisition, or learning, of a motor skill involves gradual improvement both in understanding of the environmental situation and in the type of movement involved. Once a movement goal is identified, the learner actively selects data from sensory input to which his attention will be directed. Within the central processing system, a perceptual mechanism provides for stimulus analysis: an evaluation of the current situation and/or a prediction of a future situation based on successive sampling of environmental stimuli. A translation mechanism provides for general decision-making: determination of the overall logic and direction of the response. Subsequently, a central effector mechanism provides for movement organization: the coordination and phasing of muscular activity involved in the response (Welford, 1960). That is, in terms of individual morphology and within the biomechanical constraints of the organism, the learner draws upon past movement experiences to facilitate the organization of a movement sequence which will allow for goal-attainment within the particular performance context. The focus of the present discussion will be the movement organization component within an information-processing system of perceptual-motor performance. Finally, the learner executes the response, monitors relevant feedback modalities, reenters the information-processing cycle, and makes a decision relative to the nature of his next response.

Movement organization may be defined as the functional spatial/temporal relationship between the component structural elements of a motor act. A series of limb displacements, organized in a particular time/space sequence, is referred to as a motor pattern (Wickstrom, 1970). The nature of movement organization, therefore, will be reflected in the functional relationships between spatial and temporal characteristics of movement, within the general structural composition of the movement pattern displayed during performance.

A number of authors (Broer, 1966; Cooper & Glassow, 1972; Wickstrom, 1970) have suggested that skill acquisition involves the development of general or fundamental motor patterns, applicable across broad categories of motor skills. The concept of a fundamental movement pattern implies the existence of a unitary scheme of movement organization which would be reflected in consistent spatial/temporal movement characteristics over a contextually broad class of performance situations.

In contrast, Gentile (1972) has proposed that the organization of a movement response is heavily dependent upon the characteristics of the environmental context in which performance takes place. If environmental conditions remain stable during performance (closed skill), components of the movement response must be organized in conformity with the relevant positional characteristics of the environment. However, if environmental conditions change during performance (open skill), consistent goal-attainment requires that both spatial and temporal characteristics of the movement be organized in conformity with environmental conditions.

Secondly, if the performance context remains the same over successive repetitions of the response, the performer will develop a consistent movement pattern, reflecting a spatial or spatial/temporal organizational scheme designed to match the recurrent environmental conditions. However, if environmental conditions change between performance trials, the organization of movement will lead to the development of more than one movement pattern; movement diversification will occur (Gentile, 1972). Further, in order to achieve the necessary match with environ-

mental changes, the performer must vary the appropriate, corresponding movement parameters. The critical question to be answered is "How does the learner accomplish the task of matching the characteristics of his movement to the characteristics of the performance environment, whether open or closed?"

Relative to sensory analysis within an information-processing system, both behavioral and neuropsychological evidence exist to support the concept that discrete elements of sensory input are attended to selectively, interpreted via a perceptual framework developed as a result of experience, and finally integrated into a meaningful percept relative to the particular goal-directed task. Considerably less evidence exists relative to the companion process of movement organization. It has been suggested that a movement response is organized in terms of an overall executive plan (Fitts, 1964) or general schema (Lashley, 1951), corresponding in certain respects to a motor percept or gestalt. The particular manifestation of this plan may vary from execution to execution, due to variations in the state of both the internal or morphological environment of the performer and the external or contextual environment of performance (Bernstein, 1967; Paillard, 1960). That is, what is observed during motor performance is essentially a series of discrete movement patterns, reflecting situationally-specific parameter values within a more general plan or "higher directional engram," (Bernstein, 1967) generated and regulated by central effector processes. The questions to be answered include: "What parameters of movement are critical in the formation of an overall motor plan?" "Within a given plan of movement, what are the organizational characteristics of such factors as spatial organization and extent of movement; temporal sequencing and duration of movement; velocity, acceleration, and force characteristics?" "How is adaptation accomplished within the general framework of response?"

Several broad areas of motor skills research are related to the investigation of the process of movement organization. First, the application of time/motion study to the performance of industrial tasks has produced a valuable body of information regarding the temporal efficiency of movement in a variety of work settings. Evidence has been produced of the differential effect of practice on the duration of movement components. Over practice, the reduction in duration of movement is greater for the manipulation component than for the travel component of a response (Rubin & Smith, 1952; Rubin, Von Treba, & Smith, 1952). In addition, the direction, distance, perceptual loading, type of manipulation, and precision requirements for one component of movement appear to have a generalized, integrative effect on one or more additional components of movement within a complex serial task (Hecker, Green, & Smith, 1956; Simon, 1956; Simon & Smader, 1955). This body of research suggests both the necessity for, and the efficacy of, breaking a serial task into component elements for the purpose of analyzing spatial and temporal characteristics of the movement pattern. This conclusion seems valid with respect to the effects on performance of both environmental constraints and practice. Further, findings seem to support the proposals regarding the existence of an overall organizational scheme for accomplishing an action, the specific manifestation of which reflects task-specific spatial/temporal relationships between component elements of the movement response. However, conclusions are limited to the performance of serial tasks within a stable or closed environmental setting.

Performance in an open environment requiring prediction/anticipation of event occurrence has been the focus of a second broad group of studies investigating the timing of movement responses. Considerable evidence has been obtained rela-

tive to estimation and prediction of velocity, as well as to factors affecting performance of coincidence-anticipation tasks involving the matching of a motor response to the arrival of a moving object. However, little attention has been directed to the structural/functional characteristics of the movement employed in coincidence-anticipation tasks; indeed, the typical response employed in this area of research has been a simple key press.

The third area of related research involves cinematographic investigation of motor skill performance. Although directed to the analysis of movement patterns, research in this area has been primarily descriptive. The focus has been on performance outcomes, primarily in closed sport skills, usually for a high skill level. Systematic investigation of movement organization during skill acquisition is notably lacking. However, cinematographic studies have provided some data concerning the consistency/variability characteristics of movement patterns, as well as support for the general utility of cinematography as a research tool.

For example, Higgins and Spaeth (1972) utilized cinematographic analysis to examine movement patterns displayed during acquisition of a closed motor skill. For an invariant closed dart-throwing task, employing a single stationary target, a single, highly consistent movement pattern was developed. Further, it appeared that movement consistency was directly related to consistency in goal-attainment.

The performance of highly skilled athletes in an open skill was investigated by Hubbard and Seng (1954). A cinematographic analysis was conducted of 29 professional baseball players during batting practice in order to determine the temporal characteristics of the batting swing. Three pitching speeds were employed, ranging from 55 to 89 mph. On the basis of conclusions drawn by the authors and careful review of reported results, a number of important observations seem justified. As would be expected, the total temporal interval from release of ball to contact with the bat was ordered in correspondence with ball speed. Evidence was produced of a variable delay in both start of the forward step toward the pitcher and start of the swing of the bat; the duration of the delays was directly related to ball speed. In addition, the duration of the forward step was longest for the slowest pitch and shortest for the fastest pitch. In contrast, the duration of the bat swing was uniform across the speeds of pitches. Finally, although the initiation of both the forward step and bat swing were "geared" to ball speed, the relationship between the two response components remained constant; the start of the swing occurred consistently one film frame after completion of the forward step. It appeared that some evidence had been produced of temporal organization of the batting movement relative to speed of the pitched ball.

An open skill was also employed in the investigation of movement organization conducted by Spaeth (1973). A high-speed film record was obtained of performance of a dart-throwing task involving a spatially stable target area and three different target speeds. In the graphic display of wrist displacement data, three distinct movement patterns were displayed by each S, corresponding to performance under each of three speeds of target presentation. More specifically, the duration of movement was differential with respect to target speed. Duration of the total movement response was longest for the slow target speed and shortest for the fast target speed. The differences in total movement duration were primarily

attributable to significant differences among all target speeds in the duration of the initial or preparatory phase of movement. In contrast, movement duration was relatively constant for the terminal or action phase of the response during which the wrist moved forward toward the target. These results are consistent with those reported earlier by Hubbard and Seng (1954) for an open batting task. It appeared that a match between the temporal characteristics of the movement and the temporal characteristics of the environment was achieved by means of a strategy for the organization of movement providing for an initial movement phase of variable duration and an action phase of relatively constant duration.

Further, evidence was produced of differential temporal organization of a third reponse parameter, duration of target preview; that is, the time during which the target was visible to S prior to the start of the movement response. Measures of preview duration represented S's delay in initiation of movement following presentation of the target in the target area. The duration of preview was longer for the slow target speed than for both the medium and fast speeds of target presentation. It appeared that variable preview duration was employed within the scheme of movement organization as an additional means of temporal differentiation; the longer premovement interval seemed to comprise a delay factor within the total response pattern under the slow target speed. This interpretation is consistent with the suggestions of Schmidt (1969) and Grosse (1969) regarding the use of a premovement waiting interval as an error-correcting mechanism in coincidence-anticipation tasks. Similarly, Hubbard and Seng (1954) reported a variable delay in baseball batting in the start of both the forward step and the swing, in accord with the speed of the pitched ball.

It was concluded that for the open dart-throwing task the organization of movement apparently provided for multi-stage information-processing and subsequent updating of response characteristics on the basis of cumulative information regarding the characteristics of the moving target. It seemed that preliminary information-processing was carried out upon initial entry of the target into the target area, prior to the initiation of the response. Subsequently, the duration of the preview, or premovement interval, was adjusted in accord with the initial estimate of target speed. Secondly, the duration of the preparatory phase of movement was also differentiated in accord with target speed, apparently on the basis of information regarding target characteristics obtained through target preview. Second-stage information-processing apparently continued during execution of the initial phase of movement, providing a basis for a decision concerning the length of a seond delay in movement, prior to the initiation of the relatively consistent terminal phase of movement. Results were interpreted as providing support for the concept of environmental dependency in the organization of a movement response leading to goal-attainment in a specific situation. A fundamental movement pattern was not employed. Rather, three distinct movement patterns were employed, the characteristics of which were differentially organized with respect to the variable environmental constraints imposed upon performance.

It would seem that a viable research strategy for continuing the investigation of the nature of movement organization would be one involving systematic variation of environmental conditions for performance of a motor task, coupled with a quantitative, multi-dimensional analysis of resultant movement patterns in terms of variability characteristics of movement parameters. In examining the processing of sensory input, the research strategy generally involves direct

manipulation of discrete display or input elements, followed by a recording of S's response. Subsequently, response characteristics are employed as a basis for drawing inferences concerning the nature of selective attention, vigilance, perceptual set, perceptual constancies, and the like. In examining the processing of motor output (that is, movement organization), the research strategy must, of necessity, involve indirect manipulation of discrete motor output. That is, direct manipulation is limited to the characteristics of the performance environment to which movement characteristics must be matched. However, the result is an indirect manipulation of discrete elements of motor output, displayed as observable patterns of movement. It is the spatial and temporal characteristics of these movement patterns which serve as a basis for drawing inferences concerning the nature of movement organization.

What is needed is an examination of the total information-processing system involved in perceptual-motor performance. Exclusive investigation of the role of either sensory or motor processes, without attention to their integrative interaction within the total response system, is at best self-limiting in terms of understanding the process of perceptual-motor skill acquisition or performance. Attention must be directed to questions such as: "How does the learner move from a level of performance characterized by awkward, temporally irratic, inconsistent movement patterns, accompanied by sporadic success in goal-attainment, to a level of performance characterized by the smooth, efficient, consistent movement pattern of a highly skilled performer?" "How do Ss, within the particular morphological constraints and general biomechanical limits of the human neuro-muscular system, accomplish the task of matching movements to characteristics of the performance environment?" "What is the effect on performance of varying degrees of complexity in both perceptual and motor requirements of a task?" Identification of the degree of variability in the spatial and temporal characteristics of movement patterns during performance, and evaluation of changes in movement organization during the learning process, within a variety of performance contexts, may provide at least partial answers to these and related questions.

It would seem that valuable information for the teacher of perceptual-motor skills with regard to the process of movement organization would include identification of: (a) the critical parameters of various contexts for performance relative to their effect on movement organization, (b) the critical parameters of movement for various perceptual-motor skills in terms of their relative importance in organizing adaptive responses, (c) the consistency/variability characteristics of successful movement patterns for given categories of perceptual-motor tasks, (d) the role of differential delay in planning movement responses, and (e) the relationship between the organization of movement for total body transport or stability functions, and the limb manipulation components of motor responses. Such information could serve as the basis for decisions concerning the structuring of appropriate practice conditions so as to facilitate the organization and development by the learner of the appropriate type of movement patterns for both closed and open skills of varying degrees of complexity. Secondly, such information might suggest the most critical cues in the environment to which the learner's attention should be directed. Finally, the suggested information would enable the teacher and the learner to view perceptual-motor performance as a totality in which the learner is an active participant, involved in problem-solving, decision-making, and response planning - and to view perceptual-motor learning as an adaptive cycle in which the learner is truly a processor of information.

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